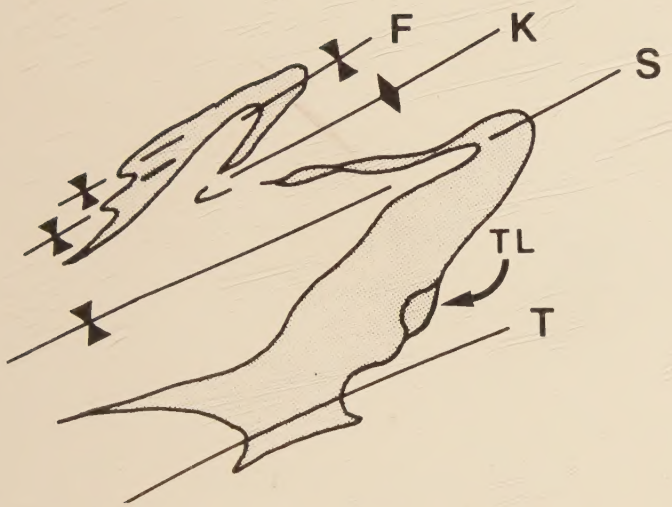
THE SNÅSA MEGA-LENS
WEST-CENTRAL SCANDINAVIAN CALEDONIDES



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Stockholm 1982.

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Andreasson, P.-G. & Johansson, L. 1982 02 25: The Snåsa Mega-lens, west-central Scandinavian Caledonides. Geologiska Föreningens i Stockholm Förhandlingar, Vol. 104, Pt. 3 , pp. 000-000. Stockholm. ISSN 0016-786x.

The northernmost closure of the Trondheim depression features a tectonic mega-lens composed of five principal units of the Swedish (Jämtland) and Norwegian (Trøndelag) allochthons. These units are the Offerdal, Särv, Seve, Gula and Støren Nappes. The Köli Nappe of the Swedish allochthon appears to have pinched out completely. The basement-cover contact has been traced westwards into the Western Gneiss Region.

The entire tectonostratigraphy was folded by the major Snåsa Synform and an associated antiform-synform pair. Folding was gentle in the eastern limb of the Snåsa Synform, and tight at the border to the gneiss region. Late high-angle faulting accentuated the fold geometry. The mega-lens folded by these folds provides further evidence of the pinch-and-swell tectonics of the Scandian (Late Silurian to Early Devonian) nappe displacement. Although sometimes less than 50 m thick, the Seve and Gula Nappes persist throughout the tight synforms. Such continuity and regular tectonostratigraphical behaviour of thin, discrete nappes suggest that the nappes travelled together in composite units subjected to extreme stretching. Basal thrusts are zones of intense attenuation and do not truncate stratigraphical sections.

Early, flattened cylindrical mesofolds with axial trends around N-S, and non-cylindrical mesofolds with similar average trends occur throughout the basement-cover sequence. Superimposed on these early folds are linear structures parallel to the ESE direction of nappe movement. These include folds, sheath folds, mineral lineations and quartz rodding. Transverse folds are common in the quartz segregations of the basal thrust and occur in the

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basement-cover contacts of the Western Gneiss Region.

The Gula Nappe preserves evidence of a pre- or early Scandian metamorphic event of medium amphibolite facies. Resting on amphibolite facies and, further down, also greenschist facies rocks, the nappe represents an inverted metamorphic gradient. The core of the tight Flåtjern Synform is occupied by epidote amphibolite facies rocks of the Støren Nappe. Adjacent on both sides occur decidedly higher-grade schists of the Gula Nappe. Post-thrusting metamorphism above greenschist facies grade is conspiciuous in zones of concentrated strain. Except for felsitic and calcareous lenses, the stretching lineation is penetrative in the upper, more strongly metamorphosed nappes. The lower nappes (i.e. Särv, Offerdal, porphyry-granite nappe) may, in contrast, exhibit primary sedimentary and igneous textures and were on the whole less ductile during the Scandian nappe displacement. Such contrasts of metamorphism and ductile deformation in the cover militate against orogenic models which see this part of the Western Gneiss Region as the deep and central zone of the orogen. With regard to post-thrusting tectonometamorphism ("Caledonization") of basement and cover, the Snåsa area represents a zone of remarkably rapid change. ☐ Nappes, thrusts, basement-cover relations, mega-lens, pinch-and-swell tectonics, ferrotschermakite, sulphide mineralization, Jämtland Supergroup, Offerdal Nappe, Särv Nappe, Seve Nappe, Gula Nappe, Støren Nappe, Grong-Olden Culmination, Tømmeråas Window, Western Gneiss Region, Snåsa Synform, Caledonides, Scandes, Trondheim region, Trøndelag, west-central Norway, N0000 N0000 E0000 E0000.

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Introduction

Recent correlation between units of the Tømmerås area (Fig. 1) and principal nappes situated 100 km to the east (Jämtland, Sweden) definitely established the allochthonous nature of the entire cover sequence in the northern Trondheim region (Gee 1974, 1977). The estimated travel distances of the allochthon thereby increased considerably. A mega-lens concept (Gee 1978) emerged from the recognition that nappe displacement was partly achieved by stretching, and from the field evidence of a characteristic mega-lens geometry of the allochthon (Gee 1976, 1978; Häggbom 1976, 1980; Kautsky 1978). Earlier work had demonstrated conspicuous wedging-out of the eastern allochthon towards the west (Rutland & Nicholson 1969; Zachrisson 1969, 1973).

The Steinkjer Mega-boudin (Fig. 1) is composed of three units which can be correlated with the Offerdal, Särv and Seve Nappes of the Jämtland allochthon (Andréasson et al. 1978). Mylonitic and phyllonitic rocks define the lower (Andréasson 1978) and upper (Peacey 1964) contacts of the mega-boudin. The tectonic nature of the internal contacts of the mega-boudin is often less conspiuous in the field but is revealed by other criteria such as metamorphic breaks and fabric contrasts.

As defined here, the Snåsa Mega-lens comprises the entire cover sequence above the Precambrian crystalline rocks of the Grong-Olden and Tømmerås culminations i.e. units of the Offerdal, Särv, Seve, Gula and Støren Nappes. The lens covers the closure of the Snåsa Synform, and the small Flåtjern Synform (Figs. 1, 3). The southwestern boundary of the lens is conveniently drawn where the Snåsa Synform narrows between the Tømmerås Window and the Western Gneiss Region.

The Snåsa Synform separates the Tømmerås basement-cover succession from the Western Gneiss Region (Vestranden). In the latter area, basement-cover relationships have been the subject of much controversy (for review, see Carswell 1973; Nicholson 1979). While some geologists (Råheim 1977, Råheim

et al. 1979) restrict the cover to very limited areas, others advocate an extensive allochthonous (Gee 1975, 1978, 1980) or autochthonous (Ramberg 1944, 1967, 1973; cf. also, however, 1977 p. 647) cover, which in the latter case is inferred to be too intensely folded and metamorphosed to be readily identified.

This paper considers the extension and geometry of the principal nappes of the Jämtland and Trøndelag allochthons in the Snåsa area. New evidences for the mega-lens geometry and the unequilibrated metamorphic nature of the cover succession in the western windows are presented. The basement-cover contact is traced out into the Western Gneiss Region.

This paper is focused on the Gula, Seve and Särv Nappes, and treats the uppermost (Støren) nappe and sub-Särv units cursorily. These subjects will be treated in special studies which are now in progress (D. Tietzsch-Tyler, Cardiff and L. Johansson, Lund). Metamorphism in the Gula Nappe will also be considered elsewhere (Andréasson 1981). Further, the reader is referred to reports on the Steinkjer Mega-boudin (Andréasson 1978, 1980) for details on deformation and metamorphism of the Offerdal Nappe metasediments.

In a reconnaissance study, Roberts (1967) described rocks and structures of the Snåsa-Lurudal area. Maps and descriptions by Birkeland (1958) and Foslie (1958)/partly cover the area of our paper. The overall structural pattern is dominated by the WSW plunging Snåsa Synform and the associated Kolåsfjell Antiform and Flåtjern Synform/(Roberts 1967) in the northwest (Fig. 3). These structures fold the regionally developed schistosities, the tectonic contacts between the various nappes and the pinch-and-swell geometry. Late, high-angle faulting accentuated the fold geometry.

Lithologies

Särv Nappe

The Särv Nappe is a characteristic principal unit of the Middle Allochthon of the Swedish Caledonides. Alluvial sandstones of probable late Precambrian

age dominate the nappe (Kumpulainen in press). Rootless dolerite dykes (Ottfjäll Dolerite ; Strömberg 1969) occur throughout the nappe and may locally predominate the bedrock. North of Lake Store Øyingen (Fig. 1), the Särv Nappe occurs in the Turtbakktjørna lens. The following brief description is based on Kautsky's report of 1978:

The feldspathic sandstones of the $\leq$ 200 m thick lens preserve cross--bedding indicating right-way up. There are pelitic intercalations and calcareous horizons. Dolerite dykes predominate over sediments. Composite dykes and coarsely plagioclase-porphyritic dykes occur in addition to typical Ottfjäll Dolerite (Strömberg 1969). Dykes in the centre of the lens are discordant and cut the bedding at high angles. Towards the margins of the lens, the dykes have been rotated into parallelism with the margins but are eventually cut by the mylonitic foliation. Garnets become more frequent towards the margin of the lens.

The approximately 500 m thick Särv lens occurring in the northern limb of the Kolåsfjell Antiform (Figs. 1-2 Section B-B) has a vertical sheet dip. It borders on blastomylonitic basement in the south. Several late, high-angle faults (p. 00) run parallel to the lens margin and obscure the contact relationships. Metadolerites of the lens can be traced without difficulty at least 2 km westwards from the Luru river and occur in hillocks 1.5 km east of the river.

The isoclinally folded feldspathic quartzites of the lens preserve no primary sedimentary features except compositional layering. Their fabric and mineral assemblages (Table 1: A76-40) are similar to those of the recrystallized feldspathic sandstones in the Särv lens of the Steinkjer Mega-boudin. There is also a dolomitic limestone which exhibits a rim of diopside hornfels where it borders on metadolerite. The mafic rocks range from conspicuously undeformed plagioclase porphyritic dolerites to strongly flattened sheets of similar mineralogy and to foliated garnetiferous amphibolites (Fig. 5). Composite dykes occur and there is also a coarsely

porphyritic type rich in both femic phenocrysts and plagioclase phenocrysts. The latter type occurs in the Steinkjer Mega-boudin, and has an alkali--basaltic composition (Andréasson et al. 1979). The preferred occurrence of post-foliation garnet growth (Fig. 5C) at strained margins, in internal shear zones indicates a strain-catalyzed process (Andréasson & Gorbatschev 1980). Preliminary chemical data from the Lurudal dykes (Table 2) indicate similarities with the Ottfjäll Dolerites (Solyom et al. 1979).

North of the Kolåsfjell-Särv lens, there occur amphibolites and mica schists of inferred Seve affinity. The situation in Lurudal illustrates a common dilemma when mapping the Särv-Seve contact in the eastern Caledonides (Strömberg 1969; Andréasson & Gorbatschev 1980). Where concordant amphibolitic metadolerites of the uppermost Särv Nappe meet the banded amphibolites of the basal Seve Nappe, the two units are easily confused if the intervening thrust is poorly exposed or developed. In these cases, the textures of garnets have diagnostic significance. Thus, while the typical garnet in the Seve rocks is wrapped in the flattening-related foliation, abundant growth of garnet in the Särv meta-dolerites post-dates this foliation (Fig. 5). North of Lake Trollvatnet, a small, tight F3--Synform projects into the basement of the Western Gneiss Region. Quartzite with sparse, concordant bands of meta-dolerite with flattened plagioclase phenocrysts occurs at the base of the cover.

Seve Nappe

The use of the term Seve is traditional in the Trondheim region (Törnebohm 1872, 1896). The metavolcanic and -sedimentary rocks of the Snåsa Synform belong to the Snåsa Group of Foslie (1958) and constitute part of the Seve Nappe in his Sanddøla map. In the Tømmerås area, Peacey (1964) referred the amphibolite facies metabasites and the mica schists of her basal Snåsa Group to the Røros schist (Gula Group). Gee (1977) correlated the basal Snåsa Group with the Seve Nappe. While Gee (1978) made a principal tectono-

stratigraphical distinction between the Seve and the Gula, Roberts (1978, Fig. 6:1) considered these units to be equivalent. In the Grong district, Kollung (1979) refers the Daergafjell Group of quartzitic rocks and the Hartkjølen mica schists and amphibolites of the Eastern Grong Complex to the Seve Nappe. However, he considers that correlation is more debatable in the Western Grong Complex, where the basal thrust below rocks equivalent to the Namsen Group is more obscure. Moreover, the Namsen Group is thought to reappear as a unit of the Helgeland Nappe in the uppermost allochthon (Kollung 1979; Råheim et al. 1979). The present paper treats the Seve and Gula as independent tectonic units. In the Snåsa area, there is field evidence of a tectonic break between the Seve and the Gula. In other areas, these nappes occupy different tectonostratigraphical levels separated by the Köli. In the type areas it is obvious that an overall geotectonic--environmental contrast exists between the Gula and the Seve. In the southern Trondheim region, Guezou (1978) identified a sub-Gula unit (Andbergshøi Complex) which he tentatively correlated with the Seve.

The Seve Nappe of the Snåsa Synform is restricted to a narrow margin of the closure. Except where lenses of Särv and Offerdal units are preserved, the Seve Nappe rests on foliated Precambrian crystalline rocks. The tectonic character of the contact between the Seve and the Gula is best studied on the slopes of Andorfjellet (Fig. 1 and Appendix: 105-106), where the Seve schists become blastomylonitic and eventually pass into a coarse augen gneiss. Northeast of the hillock called Talgsteinsberget ("Soapstone Hill") in the topographic map, a thin serpentinized ultramafic body occurs at the contact between the Seve and the Gula. In the western limb of the Snåsa Synform, the effects of thrusting are difficult to distinguished from those of late faulting (p. 00). Due to the close similarity of the Seve and Gula garnet-mica schists and amphibolites distinctions are uncertain where the tectonic contacts are poorly developed.

The Seve rock association in the Snåsa Synform is identical to that of the basal Seve allochthon in Sweden. It is dominated by garnet-mica schist and fine-grained, dark amphibolite, the latter often being inter-banded with quartzite or quartz-feldspathic gneiss. The almandine and occassional kyanite of the mica schists pre-date the regional foliation. In the vicinity of thrusts, idioblastic garnet rims often surround cores with sigmoidal inclusion trails. Similar garnets are characteristic of the contact zones of Seve units in Jämtland (Sjöstrand 1978 a.o.). The white marble which occurs in the western limb of the Snåsa Synform, is tentatively referred to the Seve. A grey fine-grained gneiss, which resembles a rock variety in the adjacent Western Gneiss Region, is also present in the Seve and may be a tectonic slice.

Gula Nappe

In the type area, the Gula Group comprises a succession of psammitic, pelitic, calcareous and bituminous sediments with subordinate mafic and felsic volcanics intruded by trondhjemite (Nilsen 1974, 1978; Nilsen & Mukherjee 1972). The folded and thrusted Gula lithologies of the Snåsa area vary strongly over short distances. The mineral compositions are diversified (Table 1) and have complex tectonometamorphic implications (Andréasson 1981). A consistent lithostratigraphic succession can only be established in areas where the Gula is less disturbed (Guezou 1978).

Mica schists predominate but often grade into calcareous or graphitic varieties. Pure quartz-mica schist is a dark, dense schist with stripes or tightly folded veins of quartz (Fig. 6). Almandine occurs as augens in the pervasive foliation defined by biotite and muscovite. Calcareous mica schist contains thin, leucocratic laminae or schlieren in a matrix of quartz, plagioclase, carbonate and zoisite. There are poikiloblasts of light grey hornblende. The leucocratic domains usually lack deformational fabric, with granoblastic quartz and plagioclase and randomly orientated

amphibole prisms. Zoisite, white mica and idioblastic almandine have static textural implication. Towards the margins of the leucocratic domains, elongated crystals have been rotated into parallelism with the regional foliation.

High lime contents in the metasediments result in massive varieties. Calcareous hornblende gneisses carry large sheaves of amphibole and almandine porphyroblasts in a matrix of quartz, ankerite and muscovite. The porphyroblasts carry folded inclusion trails of ilmenite. Brown-weathering seams of carbonate are typical features in outcrops. Where pelitic, carbonaceous and mafic compositions have been mixed, the petrology and mineralogy are exceedingly complex. Impure lime-silicate gneisses carry large amphibole porphyroblasts and cyclamen red garnets. In a granoblastic matrix of ankerite, quartz and plagioclase there occur biotite, a highly aluminous amphibole (Table 3A, ferro-tschermakite; Leake 1978), and kyanite that are overgrown by staurolite, almandine, sillimanite and zoisite. Very Al-rich amphiboles have been reported by Lagerblad (in prep.) from the Gula Nappe in Inndalen further south. They may be of diagnostic value. Their apparent rarity may, however, merely reflect the scarcity of analytical data.

Amphibolites are interbanded with felsite, marble, and ore. They always carry garnet and vary in grain size and composition from fine-grained, pure amphibolite to coarse biotite-staurolite amphibolites. Cummingtonite is a characteristic mineral of the metavolcanic and mineralized rocks. It predominates over plagioclase and quartz in fine-grained cummingtonite amphibolites, and forms clusters around ore grains in ore quartzites.

Grey, fine-grained gneisses of probably tuffitic origin carry quartz, plagioclase and mica. White, hard felsite is dissected by late fractures occupied by quartz and sulphides. The rock is occassionally composed of quartz only, but feldspar is normally present in varying amounts and may even predominate in some specimens. A fine interlamination of quartz and

feldspar can be observed under the microscope. Petrographic and chemical properties (Table 2) indicate derivation from chert or tuffite (Coleman et al. 1975; Phelps 1979) rather than quartz keratophyre, which is also suggested by the intimate association with carbonaceous and ferruginous sediments. While the silica contents of quartz keratophyres may vary considerably (Nilsen 1978), the sodium contents of the analyzed felsites appear to be too low and the potassium and magnesia contents too high for keratophyres. The manganese content of the rock is noteworthy (cf. below) against the background of the composition of the associated ores.

Small lenses of sulphide ore occur in all four limbs of the two synforms (Fig. 1: "s"). Also at Nordsjøen in the south, there occur ores and the typically associated massive, garnetiferous amphibolites. Black schists and a yellow, sulphurous sericite schist are other common lithologies. The largest ore lens is more than 15 m thick (Appendix: 18). Pyrrhotite is the predominant ore sulphide. Garnetiferous ore is a diagnostic associate. It consists of spessartine, pyrrhotite, subordinate pyrite, and Fe-poor biotite (Table 3). A high Mn/Fe ratio (Table 2) is a characteristic feature of the Gula "iron-formations" (Nilsen 1971). The mineral and whole rock chemistries of the garnetiferous ore support the alteration pattern of the high-grade Gula rocks suggested by Nilsen (1978). This alteration involved desulphurization of the ore and sulphurization of the wall-rock. On the whole, the metavolcanite-ore association at Andorfjell is very similar to the Kvikne type of Gula sulphide deposits (Nilsen 1978).

The graphite content of bituminous schists and quartzites varies strongly. There occur almost pure quartzites as well as rusty, pyritiferous black schists. In contrast to the black phyllite of the Støren Nappe, the black schist of the Gula Nappe is hard, poor in quartz veins and has a grey, rough surface.

The small ultramafic lens occurring at the Seve-Gula contact is partly serpentinized but retains minute relics of olivine in some specimens. Other parts of the lens are pyroxenitic. Whether this lens belongs to the Seve or

the Gula remains to be established. Trondhjemite dykes are concordant on a regional but cut the pervasive, thrusting-related (p. 00) foliation at low angles (Appendix: 17-18). On the eastern slope of Andorfjell (Appendix: 67), a 20 m thick trondhjemit/sheet occurs close to the basement-cover contact. The foliation of xenoliths in this sheet is parallel to the thrusting-related foliation of the wall-rock. Some trondhjemites have suffered weak necking. Their mineralogy (Table 1) indicates greenschist facies metamorphism.

Tight folding and interference by late faults often obscure the tectonic nature of the Støren/Gula contact. However, a metamorphic break is always present and intercalated Gula schists and Støren phyllites bear witness of tectonic movements along the contact. In the Snåsa area, the phyllites and metavolcanics of the Støren Nappe were metamorphosed to epidote-amphibolite facies. Some balancing of metamorphism across the contact with the Gula rocks of medium amphibolite facies is indicated by neocrystallization of garnet (Andréasson & Gorbatschev 1980, Fig. 3A).

Støren Nappe

The presence of the Støren Nappe (Gale & Roberts 1964),made up of Støren and Hovin Group rocks is well established in the Snåsa area (Carstens 1960; Roberts 1975). Principal rock types include quartz phyllites, calc-phyllites, black phyllites, conglomerates, quartzites, limestones, greenschists and meta-keratophyres.

Structures

The tectonic pattern is dominated by the late major Snåsa Synform and the Kolåsfjell Antiform and Flåtjern Synform in the northeast. These folds folded the entire tectonostratigraphy established by thrusting.

D1 structures. On the basis of metamorphic and structural criteria Andréasson (1980 p. 276) concluded that at least one major tectonometamorphic event had occurred in the Seve Nappe of the Steinkjer Mega-boudin prior to its emplacement above the Särv Nappe during the Scandian (Late Silurian - Early Devonian, Gee 1975 p. 496) nappe displacement. In consequence he distinguished this latter event as D2, a use which is retained here. Also in the high-grade allochthon of the Snåsa area, there is evidence of an early, possibly pre-Scandian event. D2 transposed and partly erased earlier structures. Fig. 6 shows the rotation of an early fabric in the calcareous Gula schist into concordance with the D2 foliation. As described above (p. 0), these incompletely transposed domains contain high-grade mineral parageneses, often with a static textural implication. However, in the Seve mica schist, the relic fabric of rotated garnets (p. 0) is more ambiguous, because P T-regimes during D2 allowed the growth of almandine and the coarsening of the fabric (Andréasson 1980). Since D2 was polyphasal (below), the internal, fine-grained fabric of the Seve garnets may well represent an early D2 structure and not necessarily a pre-D2 foliation. The continued growth of garnets during the postkinematic stage (p. 0) rather suggests a D2 age of this particular process. Precambrian ages on Seve garnets elsewhere have, however, been suggested by Reymer (1979).

D2 structures. Fig. 7 shows a mildly non-cylindrical, flattened fold in the micaceous quartzites of the Jämtland Supergroup at Varghaugan (Fig. 1). The average axial trend of the fold is N-W. Normal to this trend there is a lineation defined by fibrous quartz and white mica. Highly non-cylindrical and even completely reorientated folds are found in the same outcrop. Isoclinal folds with approximate N-S axial trends occur in the metasediments of the Offerdal and Särv Nappes of the Steinkjer Mega-boudin (Andréasson 1980). Towards the thrusts, these folds have been rotated into approximately E-W axial trends. These metasediments underwent their first penetrative deformation during the D2 event. Early isoclinal folds with axial trends around N-S are therefore in this paper termed

early D2 folds while later folds with E-W trends are designated late D2 folds. Mesostructures of late D2 age are particularly frequent in the quartz segregations of the basal thrust.

Reorientation of linear structures into the direction of tectonic movement ESE-WNW is a characteristic feature of the eastern Scandinavian Caledonides (Kvale 1953; Lindström 1961; Bryant & Reed 1969; Gee 1975). Ramsay and Sturt (1976) reported ESE quartz rodding in the "synmetamorphic" mylonites at the base of the Magerøy Nappe in Finnmark. Recent papers emphasize the importance of different mechanical properties and/or irregularities along the shear planes for the initiation of rotation of non-cylindrical folds (Rhodes & Gayer 1977; Berthé & Brun 1980; Cobbold & Quinquis 1980). Both features characterize the quartz-veined phyllonites at Varghaugan.

The prominent lineation in the Western Gneiss Region is coaxial with large-scale ENE-WSW trending folds of inferred late (D3) origin. The deviation of this lineation from the ESE-WNW dominated pattern of D2 origin in the eastern orogen has been emphasized by Ramberg (1977; cf. also in Dyrelius et al. 1980 p. 272). In his opinion, the difference is a criterion of a change to a different "movement pattern" in the west. Our observations in the Snåsa-Tømmerås area suggest that there is no abrupt change or linear trends. Moreover, ESE-WNW trends occur in the basement-cover contact at Geitfjellet (Fig. 1), i.e. in an area considered to be part of the Western Gneiss region. The difference in angle between the ESE and ENE trends is small. Careful inspection of the deformational history and rotation of the lineations back to the pre-D3 orientation by means of the stereonet is therefore usually needed in order to separate between the two.

In the far-travelled allochthon (the Seve, Gula, and Støren Nappes), the assessment of various fold generations is far more complicated. Fold style depends on factors such as rock composition and the intensity of D2 flattening and is not diagnostic of a particular fold generation (Fig. 6).

The gradual swing of axial trends from approximately N-S to E-W during D2 and their steep plunge in the Snåsa area make measurements uncertain and stereographic plots inconclusive. Mesofolds with gentle to steep plunge towards NW or SE characterize the hard schists, felsites and ore formations of the Gula Nappe (Fig. 4). Preferred orientations of hornblende have similar trends. However, local deviations to more east-westerly trends occur over short distances. The elongation of pebbles in the Hovin conglomerate east of Snåsa (Støren Nappe) plunges SSW after rotation back to the pre-D3 situation and is tentatively considered to be an early D2 structure.

The internal structure of the Gula lens at Andorfjell could be an early D2 fold (Fig. 1, 3-4). Repetition of strata and fold asymmetries suggest a recumbent antiform with eastward vergence. However, more work is needed to account for intricate repetitions of strata in the southern part of the lens. In fact, Foslie's (1958) map indicates a closure in the northern end of the lens, where three units swing westwards and pinch out. However, the same units reappear in the western periphery of the closure (Appendix: Figs. 1-2 Section A), where they have been brought to the surface and raised to steep attitudes by late high angle faulting.

D3 structures. These includes the major folds of the area, i.e. the Snåsa and Flåtjern Synforms and the Kolåsfjell Antiform. The overall axial trend of D3 folds is towards WSW (Fig. 4). There is a rapid increase in intensity of F3 folding westwards across the Snåsa Mega-lens. The small tight synforms north of Lake Trollvatnet are the forerunners of structures typical of cover units further west. Parasitic WSW-ENE folds are common. They have steep axial planes (Fig. 6B) and tend to run parallel to the megafold margin (Fig. 4).

D4 structures. Within the Grong-Olden Culmination, there occur megafolds of NW-SE orientations (Kollung 1979; Aukes et al. 1979). Frequent, late mesofolds with steep SW plunge in Lurudal area are considered to be

parasitic on the NW-SE megafolds. The mesofolds deforms D3 structures and the NW-SE megafolds are accordingly classified as D4 structures. The megafolds at Trangen (Figs. 1,4) are overturned (Kollung 1979), which is atypical of the D3 folds. Also the tight D3 folds N Trollvatnet were refolded by NW-SE trending folds (Appendix: No. 84).

Softer rocks of the cover and phyllonitic margins of the basement suffered a weak, late overprinting by crenulation along sub-horizontal axial planes. In the western limb of the Tømmerås Antiform, axial planes of these folds have very gentle dips towards the west. In the eastern limb, the dip is towards the east. Roberts (1967; cf. also Ramberg 1977, Plate 1) related these folds to gravitational "sagging" of the megastructures.

Gentle warps and local flexural slip folds have NNW-SSE trends (Fig. 4) and appear to be related to late block movements (D4).

Faulting

The prominent ENE-WSW fracture pattern of the western coast of Norway has a profound influence on the tectonic pattern of the Snåsa area. A major fault, the Trondheimsleia-Snåsavatn lineament, cuts the western limb of the Snåsa Synform. Splays of the fault influence the outlines of the Kolåsfjell basement ridge (Fig. 3). Another splay truncates the closure at Andorfjell. Where the E6 highway crosses the fault N of Snåsa, road-cuts expose 200 m of fault breccia. While the faulting at Kolåsfjell and Lake Snåsavatn suggest essentially vertical movements, sinistral shifts are indicated by the dislocated margin of the Grong Nappe complex at Bergfossen (Foslie 1958; Mapsheet Sanddøla). Judging from the work by Kollung (1979), Lutro (1979) and Roberts (1979), the fault plays a subordinate role in the Grong Nappe complex. However, the 40 km long colinear borders of the trondhjemites and the prominent topograhic expression of the Namdalen valley suggest the contrary.

Discussions of the gross regional significance and age of the deep ENE-WSW fractures of western Norway (Ramberg 1973; Roberts 1974; Ramberg et al. 1977) include a correlation with the Great Glen Fault by Vogt (Bryhni pers. comm.). In Norway, faults with similar trends were active during the Old Red deposition (Bryhni 1978; Steel 1978). Aerial pictures indicate a ductile adjustment of the cover to the fault movements as do fold asymmetries of the synforms flanking Kolåsfjell. Neocrystallization of biotite along shear planes related to the Snåsavatn fault system suggests that these faults were active while the regional temperature was still elevated. Oftedahl (1972) inferred Post-Jurassic rejuvenation along the faults.

Correlation. It appears possible to correlate the structural evolution of the Snåsa Synform with the deformational history of the Grong district. Lutro (1979) concluded, that an early event ("D0") had affected the higher--grade Helgeland Nappe prior to its juxtaposition with the lower-grade allochthon (Gjersvik Nappe). Both Lutro and Roberts (1979) recognize a two-stage development of the late Silurian phase: an early tight, isoclinal folding followed by vertical shortening and flattening related to thrusting. D1 folds of the Helgeland Nappe are often noncylindrical. Roberts (1979) reports strong transposition of bedding in conglomerates. The steep axial planes of the second phase (our D3) contrast with the horizontal extension of the first phase. The late vertical shortening ("sagging", cf. p. 00) is very prominent in the low-grade rocks of the Limingen-Tunnsjøen area.

The nature of the basement-cover contact

In accordance with the then prevalent view of authohthonous basement-cover relationships in the western Trondheim region, Oftedahl (1964) interpreted the structural parallelism between basement (Fig. 8) and cover in Lurudal as evidence of primary concordance. Recently, Råheim et al. (1979) referred to the same field evidence when they rejected the idea of a Caledonian basement-cover thrust contact at the base of the mica-schist

(p. 00) occurring along the northern and southern margins of the Grong--Olden Culmination. They combined the evidence of structural and metamorphic continuity across the contact with radiometric data from the tectonized basement and concluded that the mica-schist belongs to the basement. In their opinion, the Caledonian basement-cover contact is located much higher in the tectonostratigraphic pile. This view is clearly incompatible with our tectonostratigraphical observations along the southern margin of the culmination, and is refuted elsewhere (Johansson in prep.). All along the cover margin, the adjacent basement is blastomylonitic or augen-gneissic. Ultramylonites are as a rule very thin (<½m) or absent. When late faulting defines the contact, there occur breccias as at Kolåsfjell and NW Andorfjell . In many places, a gradual change of basement rocks towards the contact can be demonstrated.

The cover becomes increasingly foliated towards the contact with the Precambrian crystalline basement. In the Lurudal river gorge (Appendix: 28) we found a feature, which appears to be characteristic of deep thrusts in the western Trondheim region. At this locality, mica schists carry quartz segregations with fist-size aggregates of kyanite. The segregations cut isoclinal mesofolds of inferred/D2 age but are somewhat flattened by the thrusting-related foliation. Large idioblastic garnets and plagioclase cluster around the quartz aggregates. In the adjacent mica-schist, the kyanite crystals, if present, are retrogressed and like the garnets, are wrapped in the pervasive foliation (p. 00). Kyanite also grows as stellate aggregates on the thrusting-related foliation in the basal Seve contact at Trangen and in shear zones W of Geitfjellet (Fig. 1). At Varghaugan, the enrichment of Al_2SiO_5 was tentatively interpreted as evidence of differential chemical transfer and the ensuing enrichment of the relatively immobile alumina during the Scandian thrusting (Andréasson & Lagerblad 1980). Kyanite growth with post-kinematic textural implication has been reported from shear zones in the western Caledonides by Dyrelius et al. (1980, southern Trondheim region) and Ramsay and Sturt (1976, Finnmark).

The characteristic "transverse" WNW-ESE linear structures occur in the basement-cover contacts in the Western Gneiss Region (p. 00). Here, the contrast between the fissile, strongly foliated schists of the cover and the gneissic or granitic basement is still striking. Horizons of Garben-schiefer are found in the cover. Thus, even if the P T-implication of the parageneses of the contact zone does not indicate a metamorphic break, the diachronous and unequilibrated nature of the contact is obvious.

In southern Norway, Bryhni and Brastad (1980) recognized four stages of progressive tectono-metamorphism ("Caledonization") of the basement--cover contact towards the orogenic interior (i.e. westwards). While their third category adequately describes the situation also in Lurudal, the fourth category can be applied to the basement-cover contact at Geitfjellet, with due reservation for the fabric contrast mentioned above. Bryhni and Brastad (1980) state: "3) primary unconformity masked by a contact zone, up to several tens of metres thick, where there is a new foliation parallel to the overlying, often overthrust cover sequences (Kvale 1948); 4) concordant and often plastically folded contact zone where there is no apparent structural and metamorphic break between deeper levels of the basement and its immediate cover, which in most places is allochthonous (Rutland & Nicholson 1965)."

Concluding discussion

Units of the Särv and Gula Nappes occur in the northernmost closure of the Trondheim depression. Correlation with type regions of the Swedish Caledonides and the central Trondheim region is possible on the basis of overall lithological similarities as well as mineralogical and chemical particulars. The Köli Nappes of Jämtland appear to have been pinched out completely.

This study leaves the early deformational history of the allochthon largely unexplored, but confirms the mega-lens tectonics of the Scandian nappe displacement (Gee 1976, 1978). The persistence and regular tectono-

stratigraphical behaviour of discrete nappes despite their extreme thinning places constraints on the mechanism of displacement. It is difficult to imagine a model postulating that such thin nappes are slices cut out by thrusts and then pushed individually above each other. Much more likely, the nappes travelled together in composite units subjected to extreme stretching. There is, however, a difference between the western and eastern parts of the central Scandes as regards the behaviour of basal thrusts. In the frontal décollement, basal thrusts cut up-section at the leading edges, which is compatible with a displacement by gravitational spreading (Gee 1978; Cooper 1981). In the western districts, in contrast, basal thrusts do not in the same way truncate the stratigraphical sections. The basal thrust, which is a zone of intense attenuation, does not cut either up- or down-section at the leading or trailing edges.

With the exception of the competent calcareous and felsitic units of the Gula Nappe, the stretching lineation is pervasive in nappes of higher metamorphic grades. In some places (SE Lurudal), only the most competent units survived this stretching. In the lower nappes (Särv, Offerdal, porphyry-granite nappe), in contrast, primary sedimentary and igneous structures have been preserved locally. This striking difference in ductile behaviour must at least partly be due to temperature contrasts existing at the time of displacement and boudinage.

Thrust zones of the basement-cover sequence preserve isoclinal, often mildly non-cylindrical mesofolds with northerly axial trends. Rotation of these folds into the ESE direction of nappe transport resulted in a wide range of axial trends. "Transverse" linear structures occur in the Snåsa area and are particularly common in quartz segregations in the thrust above the Jämtland Supergroup. With regard to the simultaneous enrichment of Al_2SiO_5 in quartz segregations of the basement-cover contact it is tempting to declare the combined structural and metamorphic features to be a criterion of "Caledonized" thrusts. Still as far west as the Western Gneiss Region, fabric contrasts exist between basement and cover (Andréasson & Johansson 1981).

In the Western Gneiss Region, the late Caledonide (ENE-WSW) megafolds are isoclinal and have as a rule steep axial planes. In the Snåsa area, it is difficult to assess the attitudes of the fold limbs prior to faulting along the prominent Trondheimsleia-Snåsavatn lineament. In fact, the map (Fig. 1) suggests that a fairly gentle Snåsa Synform existed before the high-angle faulting. An alternative interpretation is that the ENE faulting and folding were closely related in time. The possible extinction of the fault system, if any, in the Grong area could then be due to the abrupt swing of the Caledonide trend represented by the Grong-Olden Culmination.

Some current models of the tectonic evolution of the Trondheim region propose translation of a weakly metamorphosed Støren Nappe upon the Gula in pre-Middle Arenig time (Grenne & Roberts 1980; Wolff & Roberts 1980; see also Furnes et al. 1980 for review). Strongly and multiply folded "early" thrust planes have been inferred in these models (Roberts 1978; Roberts & Sturt 1980) but have not so far been recognized by us. On the contrary, we interpret the present-day contact between the nappes as established during the Scandian nappe emplacement i.e. after the peak of metamorphism defining a marked metamorphic break. An early juxtaposition of the Støren and the Gula must imply that these nappes were metamorphosed together by the Silurian event. A continuous and normal metamorphic gradient through the Gula-Støren succession may well have existed before Scandian thrusting. The present-day metamorphic jump could have been formed by excision of part of the succession during the Scandian pinch-and-swell deformation. In the same way entire nappes have been excised in other places. However, this mechanism fails to explain the contrasts between the Støren and the high-grade Gula rocks as regards microstructural complexity and the degree of recrystallization. As long as the age and derivation of the Gula is unknown and the order and dimensions of Scandian nappe redistribution not fully established, precise statements about the early Gula-Støren relations appear to be premature.

The contrast in deformation and metamorphism between the individual

components of the Snåsa Mega-lens further strengthen the evidence of an un-equilibrated metamorphic pattern in the basement-cover sequence of the west-central Scandinavian Caledonides (Andréasson 1980; Andréasson & Lagerblad 1980; Andréasson & Gorbatschev 1980). The Gula Nappe preserves evidence of a pre- or possibly early Scandian static metamorphic event of high grade. The energy source of this event must have been located far to the west. In the southern Trondheim region, Guezou (1978) reported such an event to be restricted to the Gula rocks.

In the Snåsa area, the only post-thrusting metamorphism above greenschist facies recorded by us so far appears to be strain-induced (p. 00). These results are at variance with the recurrent hypotheses that the "deep and central zone of the Caledonides" runs along the coastline of central Norway (Ramberg 1966, 1967, 1980 p. 261 and Fig. 2, 1981 p. 130).

Acknowledgements

This work was financially supported by the Swedish Natural Science Research Council (NFR). We sincerely thank Odd Nilsen, Oslo, for critical reading and improvements of the manuscript. Roland Gorbatschev, Lund, David Gee and Hans Ramberg, Uppsala, read various drafts of the manuscript and contributed valuable suggestions. Zoltan Solyom and Ingrid Johansson, Lund, made whole-rock chemical analyses. Mineral analyses were made using the microprobe equipment of the Department of Mineralogy and Petrology, Cambridge. We thank Josef Gersner, Lund, for preparation of the large number of thin sections. Erna Hansson and Christin Andreasson, Lund, are thanked for typewriting and drawing. Special thanks go to the personell of the Snåsakroa for all kind hospitality.

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TABELLTEXTER

Table 1. Selection of mineral associations of chief rock types of the Särv, Seve and Gula Nappes from the Snåsa area. Brackets indicate that a mineral pre-dates the regional (pervasive) foliation. Italics indicate that a mineral post-dates this foliation. Mineral names are given twice if textures and/or mineral compositions suggest different generations. Plagioclase: An-content above 15 mol-%.

Table 2. Chemical composition of selected rocks from the Snåsa area. Analysts: Z. Solyom and I. Johansson, Lund. ☐ 1. Dolerite, Särv Nappe, Lurudal. ☐ 2. Ottfjäll Dolerite. Mean of 123 samples. Solyom et al. 1979. ☐ 3-7. Felsitic metavolcanic rocks, Gula Nappe, Andorfjell. Specimens CRP-A76-15 (3); -15A (4); A75-19 (5); -22 (6); -24 (7). ☐ 8. Garnetiferous ore, Gula Nappe, Andorfjell. Spec. No. CRP-A75-25.

Table 3A. Chemical compositions of hornblendes of the Gula Nappe, Snåsa area. Analysts: P.G. Andréasson, EDS equipment of Dept. of Mineralogy and Petrology, Cambridge, and B. Lagerblad, WDS-equipment of Grant Institute of Geology, Edinburgh.

Table 3B. Chemical compositions of garnets and biotites of the garnetiferous ore, Gula Nappe, Snåsa area. Analysts: cf. Table 3A.

Appendix. Location of selected key localities, such as nappe contacts, locations of principal rock types etc. Section lettering refers to Figs. 1-2. Grid numbers refer to the European Datum Mercator System. Localities are listed in order from west towards east. ☐ B. Basement. ☐ G. Gula Nappe. ☐ JS. Jämtland Supergroup. ☐ O. Offerdal Nappe. ☐ SA. Särv Nappe ☐ SE. Seve Nappe. ☐ ST. Støren Nappe. Tectonostratigraphical designations are omitted when uncertain.

FIGURTEXTER

Fig. 1. Principal tectonostratigraphic units of the Snåsa area. Nappe complexes of the Grong and Verdal districts and the basement of the Grong district are undifferentiated. Boundaries of the cover S Geitfjellet are preliminary. Barbs of nappe boundaries are Roman serial numbers and indicate the position of the nappe in the basement-cover sequence. □ SM (inset map) = Steinkjer Mega-boudin). The map employs information from Foslie (1958), Peacey (1964), Roberts (1967), Gee (1974), Kautsky (1978), Kollung (1979), Andréasson & Lagerblad (1980) and personal communication from Jan-Erik Lindqvist, Lund.

Fig. 2. Sketch block diagrams showing the structure of the Snåsa Synform. Section lines refer to Fig. 1. The end-points of the section lines are approximate. Inferred boundaries are shown by dashes. Vertical scale equals horizontal. Dips of nappe contacts are average dips measured in the field. The topography has been neglected. (The highest peak of Kolåsfjellet is about 600 m above Lake Snåsavatn, i.e. 3 mm above the C-C-B-B datum plane of Fig. 2).

Fig. 3. Planar structures of the Snåsa Synform. For nappe boundaries, cf. Fig. 1. To avoid confusion with faults, nappe boundaries are drawn in full lines even when uncertain. B = Bergfossen. Structures E Grong after Kollung (1979).

Fig. 4. Linear structures of the Snåsa Synform. Cf. the caption text of Fig. 3.

Fig. 5. Dolerites of the Särv mega-lens at Lurudal. □ A. Composite dyke. Scale bar is 50 mm. Spec. CO-KA-389. □ B. Progressive deformation of a dyke towards its margin. Scale bar is 50 mm. Spec. CO-LJ-9-224a-c. □ C. Idioblastic, zoned garnets overgrow the deformed fabric. Margin of dyke. Scale bar is 5 mm. Spec. CO-A80-207.

Fig. 6A. Transposition of an early foliation by the pervasive D2 foliation. Quartz-mica schist with calcareous domains, Gula Nappe, Andorfjell. The upper left corner is magnified in Fig. 6B.

Fig. 6B. Cf. the text of Fig. 6A. Note the transposition of the crenulation around the point of the pen.

Fig. 6C. Cf. the text of Fig. 6A. Note the progressive transposition towards the right in the picture, where early D2 folds are sheared into thin stripes. Fold axes of Figs. 6A-C plunge towards NNW.

Fig. 6D. D3 folds with steep axial planes refold the transposed D2 folds of Figs. 6A-C. Andorfjell.

Fig. 7. Non-cylindrical, flattened early D2 fold. Quartzose phyllonite, Varghaugan, Tømmerås Window. White is quartz, grey is white mica. A lineation defined by fibrous quartz (F) and small mica flakes is normal to the average trend of the curvilinear hinges of the quartz fold (c. N-S). Drawing from hand specimen, approximately natural size. Spec. No. CO-A80-192.

Fig. 8. Augen gneiss from the basement-cover contact S Lurudal (Appendix: 40). Scale bar is 50 mm. Spec. No. CO-A76-56.

Särv Nappe

meta-arkose	A76-40	quartz + plagioclase + K-feldspar + green biotite + white mica + epidote + sphene
meta-arkose	A80-164	quartz + plagioclase + K-feldspar + biotite ± garnet
quartzite	A76-44	quartz ± biotite ± white mica ± epidote ± carbonate
dolomite	A76-41b	dolomite
hornfels	A76-41c	diopside ± carbonate ± tremolite
meta-dolerite	A80-222	plagioclase + hornblende + (clinopyroxene) + zoisite + quartz + garnet + sphene
meta-dolerite	A80-221	hornblende + plagioclase + (clinopyroxene) + tremolite quartz + zoisite + garnet + rutile
amphibolite, plagioclase porphyritic	A80-165	hornblende + plagioclase + zoisite (plagioclase mega-cryst pseudomorphs) + quartz ± sphene ± biotite
amphibolite	A80-168	hornblende + plagioclase + quartz + Fe-oxides + sphene + garnet

Seve Nappe

mica-schist	A75-7, A76-59	quartz + biotite + plagioclase + K-feldspar + muscovite + (almandine) ± kyanite
mica-schist	A76-134	biotite + muscovite + quartz + plagioclase + K-feldspar + tourmaline ± hornblende
mica-schist	A76-74	quartz + biotite + plagioclase + K-feldspar + muscovite + kyanite + zoisite
quartzite	A78-143	quartz + biotite + white mica + garnet
amphibolite	A76-142	hornblende + plagioclase (normally zoned) + quartz + epidote + sphene + garnet

Gula Nappe

micaceous quartzite	A80-193	quartz + white mica + garnet
	A80-214	quartz + plagioclase + biotite + sillimanite
mica schist	A75-22	quartz + biotite + (biotite) + muscovite + plagioclase + K-feldspar + (almandine) ± (kyanite) ± (staurolite) + tourmaline
mica schist, calcareous	A75-151	quartz + biotite + plagioclase + carbonate + kyanite + zoisite + amphibole (stellate)
	A75-78	quartz + carbonate + white mica + biotite amphibole + staurolite + (kyanite) + Fe--oxides + tourmaline
calcareous domain in mica schist	A75-34	sodic plagioclase + zoisite + white mica + quartz + myrmekite + garnet + carbonate + amphibole + apatite ± rutile
	A75-34	quartz + zoisite + carbonate + cummingtonite + sphene
hornblende schist, calcareous	A75-[illegible]	Al-amphibole + biotite + ankerite + plagioclase quartz + muscovite + staurolite + almandine + kyanite + (ilmenite) + chlorite ± tourmaline
	A80-193	biotite + quartz + plagioclase + staurolite + amphibole + kyanite + chlorite + white mica + carbonate
	A76-149	ankerite + plagioclase + quartz + stellate hornblende + muscovite + (quartz) + (ilmenite) + epidote + clinozoisite + apatite
	A75-25	ankerite + labradorite + quartz + Al-amphibole + almandine + muscovite + biotite + chlorite + rutile ± staurolite ± kyanite ± fibriolite ± (ilmenite)

Table 1 forts 2

marble, impure	A76-78	carbonate + plagioclase + quartz ± amphibole ± garnet ± white mica ± biotite ± Fe-sulphides
	A76-21	carbonate + plagioclase + quartz + zoisite + kyanite + white mica + rutile ± amphibole ± garnet
	A75-25	diopside + plagioclase + zoisite + quartz + biotite + amphibole + clinozoisite + sphene + microcline + chlorite
black schist	A75-24	quartz + graphite + white mica + Fe-sulphides
black mica schist	A75-15	quartz + white mica + graphite + (Mg-biotite) + (almandine) + pyrrhotite + tourmaline
black quartzite	A76-16	quartz + graphite + white mica + magnetite + pyrrhotite ± biotite ± garnet
	A75-20	quartz + white mica + graphite + Fe-sulphides ± plagioclase
grey, fine-grained schist	A76-165	quartz + (biotite) + white mica + andesine + (garnet) + (kyanite) + tourmaline
	A76-166	(labradorite) + quartz + (Mg-biotite) + white mica + (pyrite) + (fibriolite) + tourmaline
felsitic rock	A75-23	quartz + plagioclase + K-feldspar ± Fe-sulphides
	A75-20	quartz + oligoclase-andesine ± pyrrhotite ± amphibole
	A75-20	interbanded: quartz + white mica and plagioclase + K-feldspar + white mica + sphene + zoisite
metavolcanic rock	A80-193	(quartz-feldspar matrix) + (albite phenocrysts) + biotite + muscovite + white mica + chlorite
trondhjemite dyke	A75-17	quartz + plagioclase + albite + green biotite + epidote + white mica + sphene + garnet + apatite

Table 1 forts 3

	A77-69	quartz + albite + plagioclase + white mica + apatite ± hornblende ± epidote
sericite quartzite	A76-150	quartz + muscovite + garnet + garnet + pyrrhotite + magnetite + Fe-carbonate
ore	76-161	pyrrhotite + graphite + quartz + plagioclase + biotite + muscovite + Mn-garnet
	A80-193	quartz + pyrrhotite + pyrite + white mica
	A76-150	quartz + plagioclase + white mica + Fe-sulphides + graphite + carbonate + apatite
garnetiferous ore	A75-25	quartz + spessartine + pyrrhotite + Mg-biotite + pyrite
amphibolite	A80-193	hornblende + plagioclase + carbonate + biotite white mica + quartz + zoisite + rutile
	A76-24	hornblende + plagioclase + quartz + garnet + Fe-Ti-oxide + pyrite
cummingtonite amphibolite	A76-163	cummingtonite + grünerite + labradorite + quartz + white mica ± carbonate ± sphene ± garnet ± zoisite ± tourmaline
ultramafic rock	A77-62	cummingtonite + zoisite + plagioclase + chlorite + tourmaline
	A77-64	clinopyroxene + tremolite + chlorite + Fe-oxide + carbonate + clinozoisite
serpentinite	A77-63	serpentine + olivine + Fe-oxide.

Table 2

No. ...	1.	2.
SiO_2	50.6	50.5
TiO_2	1.5	1.3
Al_2O_3	15.7	15.6
Fe_2O_3	3.4	2.0
FeO	7.4	7.7
MnO	.18	.17
MgO	5.6	7.0
CaO	10.9	11.1
Na_2O	2.6	2.4
K_2O	.5	.6
P_2O_5	.18	.17
H_2O^-	.21	.06
L.O.I.	1.5	1.5
Rb	10	16
Sr	253	255
Y	32	26
Zr	120	96

Table 2. (continued) forts. 1

No. ...	3	4	5	6	7
SiO_2	78.7	61.3	77.4	64.9	67.1
TiO_2	.5	1.0	.6	1.0	.6
Al_2O_3	8.7	16.4	9.9	14.8	10.5
Fe_2O_3 tot	3.5	8.1	3.6	6.7	6.5
Fe_2O_3	-	-	.3	.3	-
FeO	-	-	3.0	5.8	-
MnO	.13	.10	.10	.06	.14
MgO	2.7	3.8	2.6	3.8	2.4
CaO	1.5	1.4	1.1	1.7	2.6
Na_2O	.9	1.4	.5	1.3	1.0
K_2O	2.1	3.6	2.4	3.7	2.6
P_2O_5	.04	.19	.05	.16	.30
H_2O^-	.07	.16	.05	.10	.30
L.O.I.	1.5	2.7	2.4	2.2	5.4
Total	100.34	100.15	100.40	99.82	99.44

Table 2. forts. 2

No.	8
SiO_2	37.0
TiO_2	.6
Al_2O_3	10.0
Fe_2O_{3tot}	20.5
MnO	9.0
MgO	4.1
CaO	3.7
Na_2O	.1
K_2O	1.2
P_2O_5	.8
H_2O^-	.8
L.O.I.	11.4
Total	99.2

Table 3 A.

Hornblendes

No. ...	A75-21	A75-25B	A75-25C	A75-25D	A75-25E
SiO_2	39.3	41.3	41.8	41.7	43.0
Al_2O_3	20.3	19.0	18.5	20.4	17.9
TiO_2	.3	.4	.5	.3	.4
FeO_{tot}	14.5	16.3	15.9	15.7	14.3
MgO	7.6	7.2	8.4	7.4	9.6
MnO	-	-	.1	.1	-
CaO	10.6	10.8	10.0	10.3	10.3
Na_2O	1.7	1.5	1.8	1.7	1.6
K_2O	.4	.6	.3	.3	.2

Table 3 B.

Garnets

No. ...	A76-161	A75-25
SiO_2	37.7	38.0
Al_2O_3	22.1	21.3
TiO_2	-	.2
FeO_{tot}	16.5	7.5
MnO	13.0	31.0
CaO	6.0	2.8
MgO	4.2	2.1

Biotites

SiO_2	37.3	39.7
Al_2O_3	18.6	15.5
TiO_2	1.2	1.1
FeO_{tot}	8.1	8.6
MnO	0.2	0.8
MgO	17.0	18.8
K_2O	9.3	9.8

Section A - A	UTM 33W UM	
1. Basement porphyry, blastomylonitic (B)	932 392	river
2. Basement-cover contact: vertical fault with mylonite, breccia (B)	9325 390	river, road
3. Felsitic rock with sulphides (G)	9325 3895	road
4. Quartz veined mica schist (G)	933 389	W bridge
5. Sulphide ore (G)	934 388	E bridge
6. Calcareous mica schist; hornblende schlierens (G)	934 387	road, river
7. View from road westwards: D3 mesofolds, parasitic.	934 3865	western river bank
8. Calcareous mica schist; brown seams (G)	9345 3855	road, river
9. Bituminous quartzite. Sulphides (G)	934 3865	road
10. Calcareous hornblende gneiss with intercalations of felsite and marble (G)	936 385	road
11. Calcareous mica schist, hornblende schlieren. Locality of Figs. 5A-C (G)	9425 380	road turn
12. Grey, fine-grained gneiss (meta-keratophyre) (G)	9455 3785	road
13. Intercalated marble/amphibolite (G)	951 3755	road
14. Lime-silicate rock. Amphibolite (G)	952 3755	road
15. Felsitic rocks	953 3755	road
16. Bituminous schists, quartzites. Ferruginous quartzite (G)	9545 3725	road
17. Trondhjemite dykes (G)	9565 372	road
18. Sulphide ore. Trondhjemite dyke (G)	957 372	road
19. Mica schist with intercalated ferruginous quartzite. Sulphides (G)	959 3715	road
20. Calcareous mica schist (G)	961 371	road

21.	Amphibolite, fine-grained (SE?)	9625 372	marsh N road
22.	Quartzite (SE?)	964 3715	road
23.	Mica schist, rich in garnet, crenulated (SE?)	9645 3715	wall N road, W clearance
24.	Blastomylonitic basement (B)	965 3705	river, low water level
Section B - B		UTM 33W UM	
25.	Blastomylonitic basement (B)	780 430	river bank
26.	Vertical fault. Breccias	782 428	railway
27.	Basement-cover contact	783 427	river gorge
28.	Garnet-mica schist; kyanite pods (SE)	783 427	ropeway
29.	Sulphide ore. Amphibolite. Cummingtonite amphibolite (G)	784 427	foot-path NE tunnel
30.	Støren/Gula contact. Garbenschiefer	786 4255	railway
31.	Greenschist. Keratophyre (ST)	790 424	tunnel
32.	Støren/Gula contact. Garbenschiefer	791 422	tunnel
33.	Calcareous mica schist. Garnet amphibolite (G)	794 419	tunnel
34.	Bituminous schist. Felsitic rock. Sulphide mineralization (G)	797 418	tunnel, southern gate
35.	Amphibolite, quartz-feldspathic gneiss (SE)	799 4165	river, railway
36.	Plagioclase porphyritic metadolerite. Meta-arkose (SA)	800 415	sewage tunnel below railway
37.	Garnetiferous metadolerite (SA)	7985 413	road-cut
38.	Blastomylonitic basement (B)	802 411	railway
39.	Granite (B)	807 385	hillock
40.	Augen gneiss (Fig. 7) (B)	805 367	railway, road
41.	Garnet-mica schist (SE	8105 3655	tunnel, northern gate

42.	Hard metabasite. Sulphide ore (G) Garnetiferous ore	8115	364	tunnel, southern gate
43.	Greenschist (ST)	813	363	railway
44.	Greenschist (ST)	848	360	stream
45.	Conglomeratic phyllite (ST)	806	303	road-cut
46.	Phyllonitic quartz phyllite (ST)	869	3415	bridge
47.	Hornblende garbenschiefer with garnets (ST-G)	8875	354	road turn
48.	Bituminous quartzite. Fault zone (G)	887	3525	road
49.	Mica schist. Transposition of quartz veins (G)	8845	350	stream
50.	Calcareous mica schist with hornblende schlieren (G)	885	349	road, slope
51.	Sulphide ore (G)	885	347	road
52.	Grey, fine-grained gneiss (G)	885	347	road
53.	Lime- silicate gneiss (G) (54-56 below partly overlap 46-49).	887	346	road turn
54.	Bituminous, sulphide-rich schist. Sericite schist (G)	8505	3185	northern river bank
55.	Intercalated mica schist and quartz phyllite. Garbenschiefer.(G-ST)	848	315	river
56.	Garnet-mica schist. Quartz-veined mica schist (G)	854	317	river
57.	Calcareous mica schist (G)	843	305	road
58.	Calcareous hornblende gneiss (G)	846	306	road
59.	Yellow sericite schist (sulphur)(G)	850	306	road
60.	Mica schist with intercalations of cummingtonite amphibolite (G)	8555	3055	road

61.	Quartz-veined mica schist with marble and ore horizons (G)	873	3065	river, road
62.	Cummingtonite amphibolite (G)	874	3055	road
63.	Calcareous hornblende schist (G)	878	303	river
64.	Coarse garnet amphibolite (G)	880	3015	river
65.	Yellow sericite schist. Grey, fine--grained gneiss (G)	883	2985	road
66.	Calcareous mica schist. Grey, fine--grained gneiss.Trondhjemite dykes (G)	885	296	slope
67.	Trondhjemite dyke with xenoliths (G)			white outcrops
68.	Black schist rich in sulphides (G)	883	293	small scarp
69.	Brown garnet-mica schist (G or SE)	890	288	slope
70.	Greenschist (retrogressed Seve amphibolite?)			small outcrop, end of road
71.	Banded amphibolite (SE)			slope
72.	Garnet-mica schist (SE)			slope
73.	Amphibolite (SE)			small scarp
74.	Basement-cover contact. Augen gneiss, grading eastwards into blastomylonitic basement.			hillocks W small lake

Section C - C		UTM 33W UM		
75.	Red and grey fine-grained gneiss (B)	684	384	
76.	Augen gneiss. Winding structures (B)	688	375	
77.	Garnet amphibolite (SE)	691	375	
78.	Quartz-veined schist (SE)	692	375	
79.	Garnet amphibolite (SE)	713	398	road
80.	Garnet-mica schist. Felsitic rock. Sulphide ore (G)	7125	397	road

81.	Grey gneiss (B?)	713	387	road
82.	Fault breccia	715	384	road
83.	Fault. Mixed units: grey gneiss, marble, metabasite, felsite	7145	374	road
84.	Metabasite. Gneiss (B?)	715	370	below power line
85.	Marble (SE)	717	366	road
86.	Marble. Metabasite. Garnet-mica schist (SE)	7175	362	road
87.	Garnet amphibolite. Marble (SE)	718	355	road
88.	Greenschist. Keratophyre (ST)	718	348	road
89.	Basement porphyry (B)	753	360	slope
90.	Blastomylonitic porphyry (B)	753	358	stream
91.	Mylonite. Phyllonitic schist (B)	7505	355	stream
92.	Quartz-veined mica schist	750	353	stream
93.	Greenschist with keratophyre (ST)	749	349	timber lane
94.	Conglomerate (ST)	751	2715	road
95.	Quartz phyllite (ST)	7835	2585	road
96.	Greenschist. Garbenschiefer (ST)	7835	255	stream
97.	Hard, quartz-veined schist (G?)	784	2545	below bridge
98.	Bituminous quartz schist (G)	784	2535	road
99.	Garnet-mica schist (G)	7865	2535	road
100.	Trondhjemite dykes. Black, bituminous schist. Mica schist (G)	7865	2535	road
101.	Felsitic, sulphide-rich rock. Sulphide ore (G)	788	2515	stream
102.	Dense metabasite	793	251	road
103.	Serpentinized ultramafic rock	797	2515	road
104.	Ditto	798	252	road
105.	Tectonized garnet-mica schist	799	251	road

106.	Augen schist.	7965	2495	hillock 250 m SW from road
107.	Amphibolite with hornblende porphyroblasts (SE)	8005	2495	road
108.	Garnet amphibolite (SE)	804	246	western shore of small lake
109.	Fine-grained amphibolite (SE)	808	235	marsh
110.	Meta-arkose. Metadolerite (SA)	8115	231	brook near lake
Section D - D		UTM 33W UM		
111.	Pink fine-grained gneiss. Garnet amphibolite (B)	675	345	bare mountain
112.	Augen gneiss	681	339	northern end of lake
113.	Garnet-mica schist.Amphibolite (SE)	691	348	brook
114.	Marble (SE)	6935	3485	road
115.	Greenschist (ST)	701	3495	road
116.	Greenschist with epidote pods. Keratophyre (ST)	695	233	road
117.	Greenschist (ST)	7205	224	S bridge
118.	Mica schist. Amphibolite. Quartz-feldspathic gneiss (SE)	7225	218	brook
119.	Garnet amphibolite (SE)	728	218	brook
120.	Amphibolite (SE)	7345	216	below power line
121.	Amphibolite (SE?)	7535	201	hillocks
122.	Quartzite. Metabasite (SA?)	755	198	hillocks
123.	Quartz-veined mica schist (O?)	7585	1935	small lake
124.	Mica-chlorite schist (O?)	753	190	brook
125.	Schistose basement rock (B)	753	188	slope
126.	Well preserved grey porphyry (B)	745	1765	road

Section E - E		UTM 33W UM		
127.	Red gneiss, rich in magnetite (B)	553	265	bare mountain
128.	Blastomylonite (B)	553	262	road, slope
129.	Basement-cover contact. Gneiss. Marble	559	2615	road turn, valley
130.	Amphibolite with sulphides. Trondhjemite dykes (G)	557	260	road
131.	Fault zone. Marble breccia	561	2585	road
132.	Greenschist (ST)	5585	2545	road
133.	Phyllonite. Phyllite (JS)	595	182	northern and southern shores
134.	Phyllonitic basement. Quartzite (JS)	615	101	low scarp
135.	Limestone (JS)	608	0945	brook
136.	Black schist/phyllite (JS)	607	0935	brook
137.	Quartzite. Phyllite (JS)	607	086	brook
138.	Garnetiferous greenstone. Garbenschiefer (B)	603	0845	brook
139.	Blastomylonitic basement	615	0865	ridge
Section F - F		UTM 32W PS		
140.	Microcline granite. Red gneiss (B)	420	2725	p. 553
141.	Blastomylonitic granite (B)	406	262	northern shore
142.	Biotite-rich phyllonite. Grey gneiss	405	2615	island (low water level)
143.	Intercalated amphibolite, quartz--feldspathic gneiss, and marble (SE?)	406	259	cape in lake
144.	Marble (SE?)	404	258	cottage
145.	Seve-Gula contact? Garbenschiefer. Sulphide ore. Hard amphibolite. Felsitic rock.	407	254	road

146.	Greenschist (ST)	410	228	valley
147.	Phyllonitic basement	430	168	rock-carving
148.	Metadiorite (hanging wall)	443	163	cliff N road
149.	Phyllonite. Quartzite (JS)	445	165	cliff N road
150.	Quartz segregations with plagioclase and garnet. Phyllonite rich in kyanite. Non-cylindrical quartz mesofolds (B, JS)	445	165	scree, large boulders along road

FIG. 1.

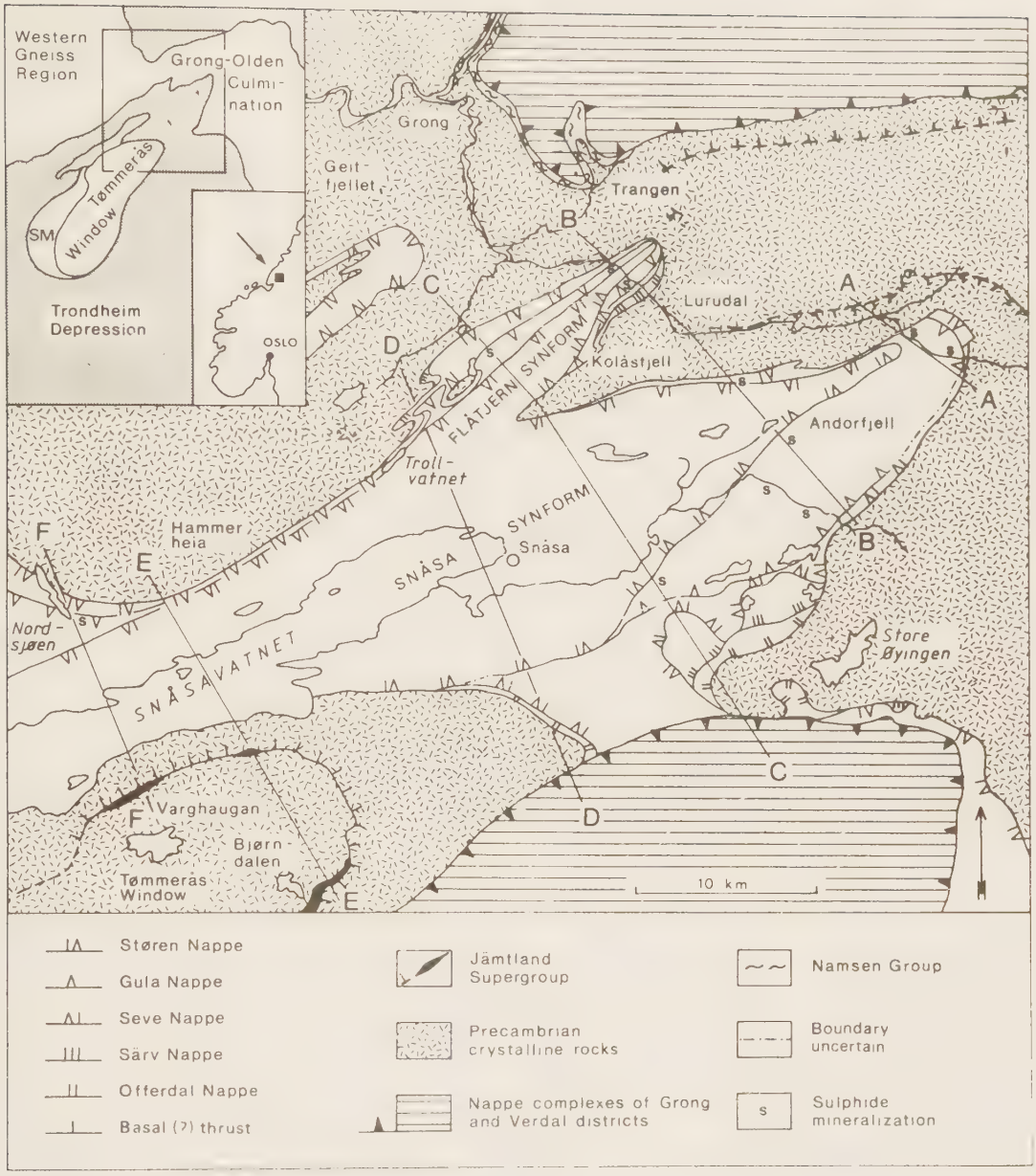

Western Gneiss Region
Grong-Olden Culmination
Tømmerås Window
SM
Trondheim Depression
OSLO
Grong
Geitfjellet
Trangen
Lurudal
Kolåstjell
FLÅTJERN SYNFORM
Andorfjell
Trollvatnet
SYNFORM
Snåsa
SNÅSA
SNÅSAVATNET
Hammerheia
Nordsjøen
Store Øyingen
Varghaugan
Bjørndalen
Tømmerås Window
10 km
A
B
C
D
E
F
Støren Nappe
Gula Nappe
Seve Nappe
Särv Nappe
Offerdal Nappe
Basal (?) thrust
Jämtland Supergroup
Precambrian crystalline rocks
Nappe complexes of Grong and Verdal districts
Namsen Group
Boundary uncertain
Sulphide mineralization
S

FIG. 2.

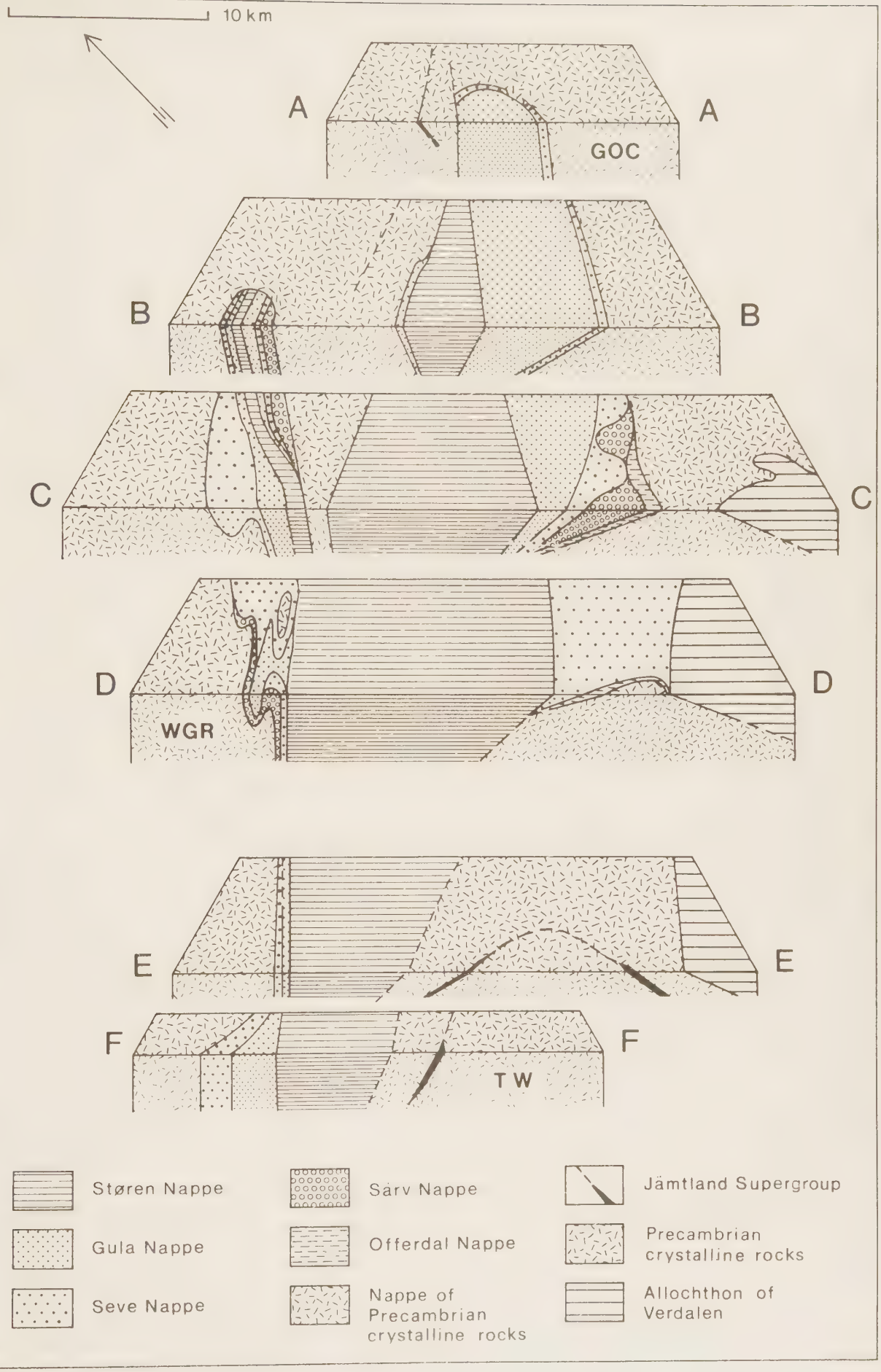

10 km
A
A
GOC
B
B
C
C
D
D
WGR
E
E
F
F
TW
Støren Nappe
Gula Nappe
Seve Nappe
Särv Nappe
Offerdal Nappe
Nappe of Precambrian crystalline rocks
Jämtland Supergroup
Precambrian crystalline rocks
Allochthon of Verdalen

FIG. 3.

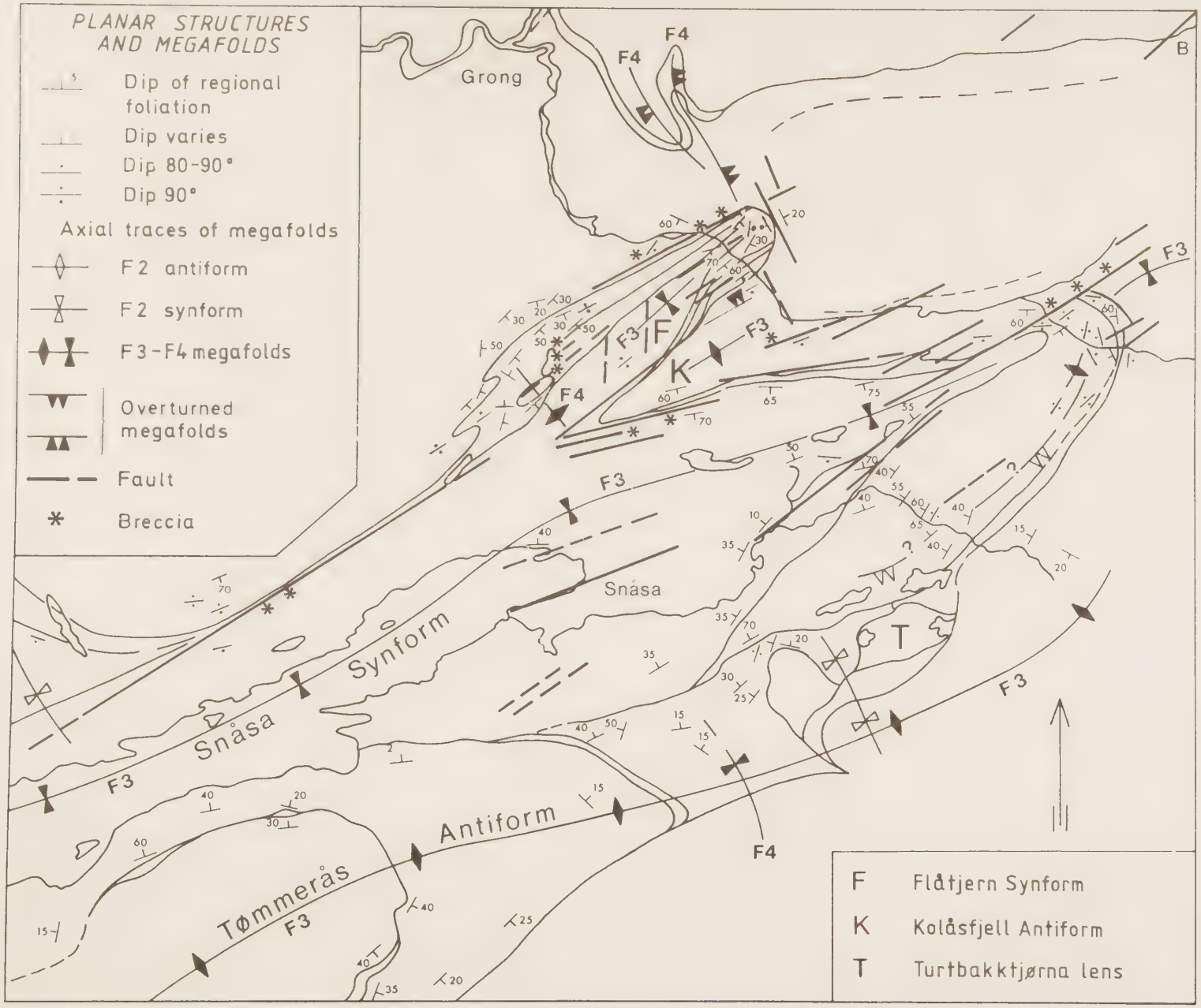

PLANAR STRUCTURES AND MEGAFOLDS
Dip of regional foliation
Dip varies
Dip 80-90°
Dip 90°
Axial traces of megafolds
F2 antiform
F2 synform
F3-F4 megafolds
Overturned megafolds
Fault
Breccia
Grong
B
F4
F3
F
K
T
Snåsa
Synform
Antiform
Tømmeråsa
F
Flåtjern Synform
K
Kolåsfjell Antiform
T
Turtbakktjørna lens

FIG. 4.

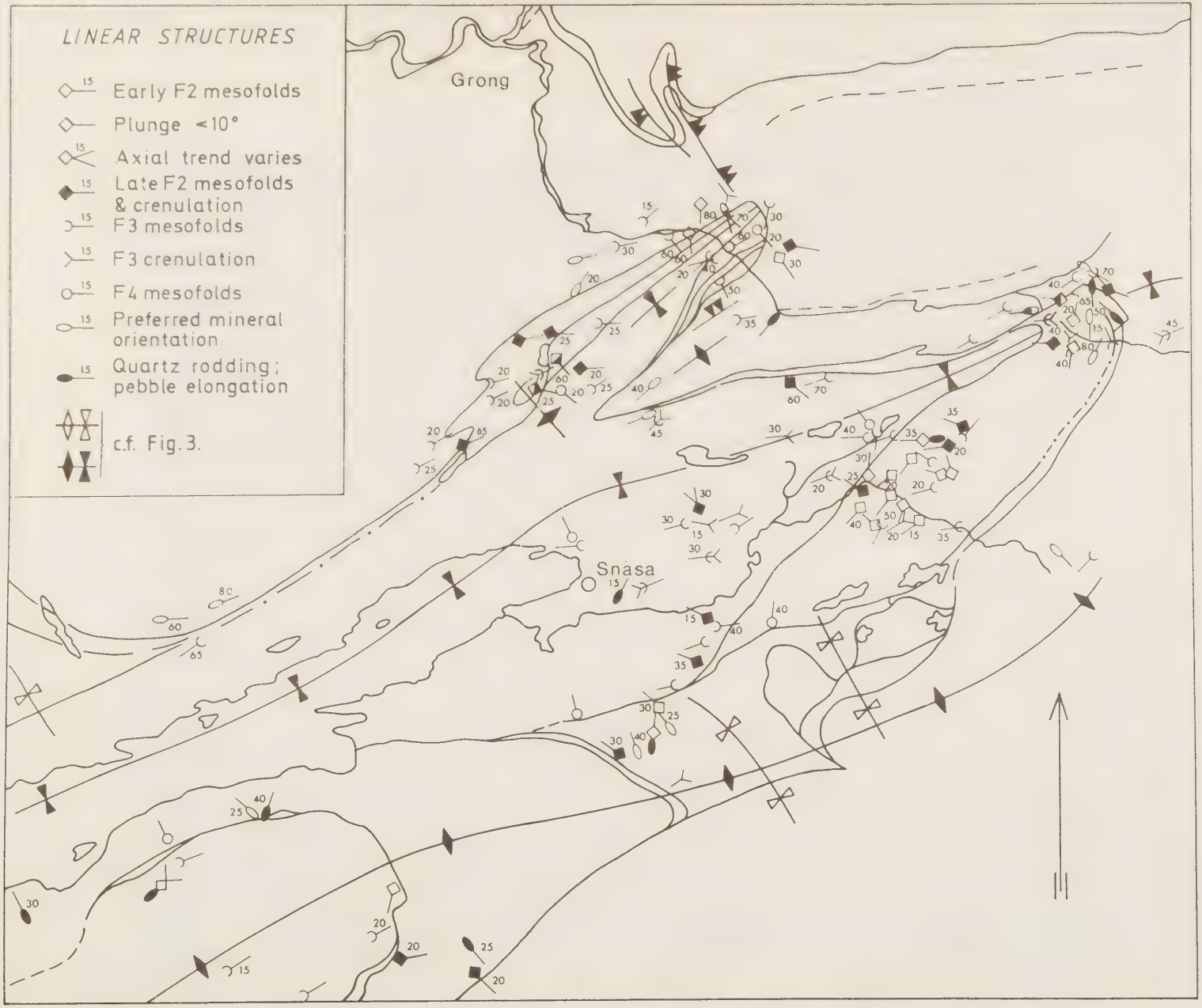

LINEAR STRUCTURES
Early F2 mesofolds
Plunge <10°
Axial trend varies
Late F2 mesofolds & crenulation
F3 mesofolds
F3 crenulation
F4 mesofolds
Preferred mineral orientation
Quartz rodding; pebble elongation
c.f. Fig.3.
Grong
Snåsa

FIG. 5.

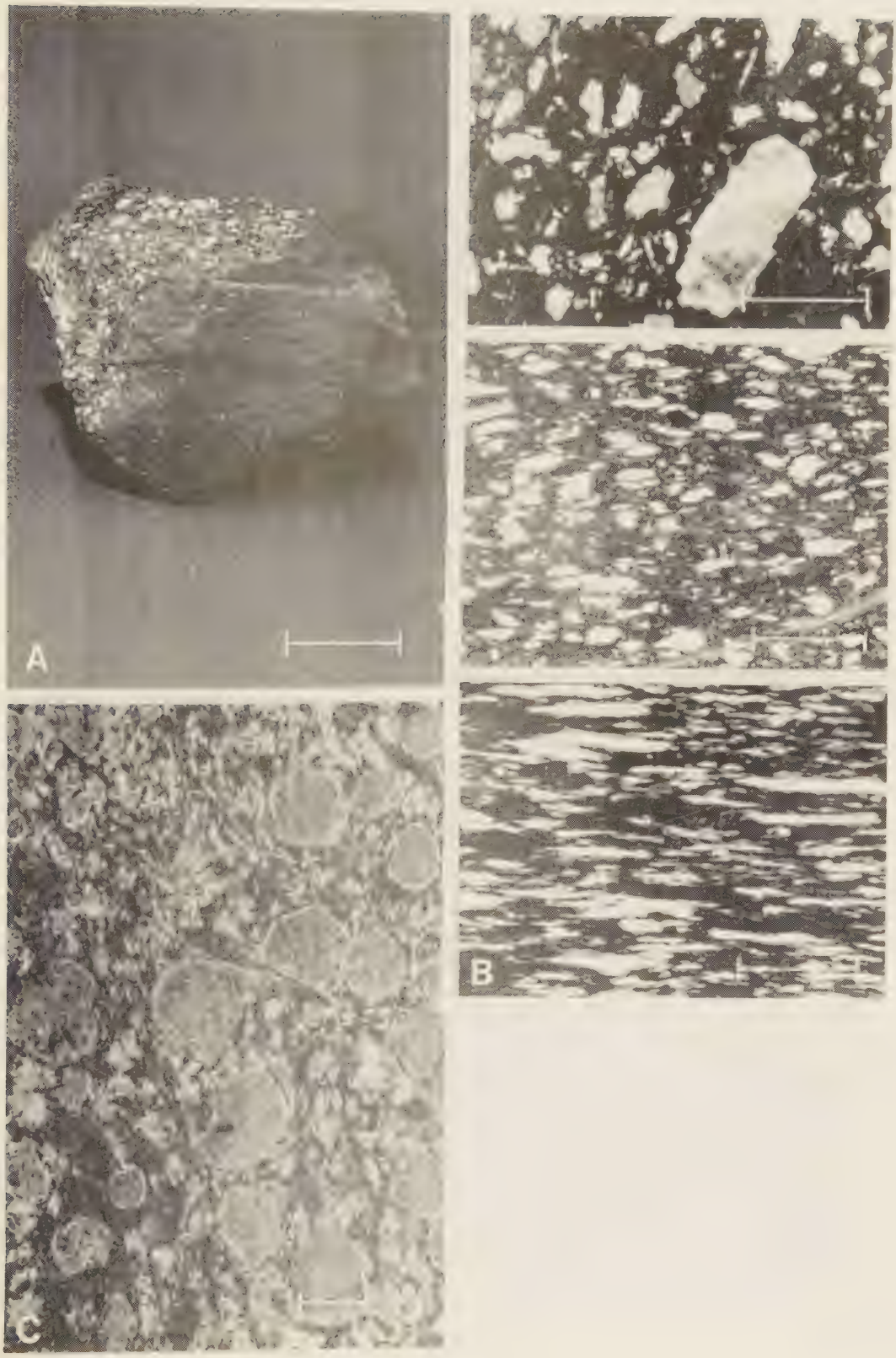
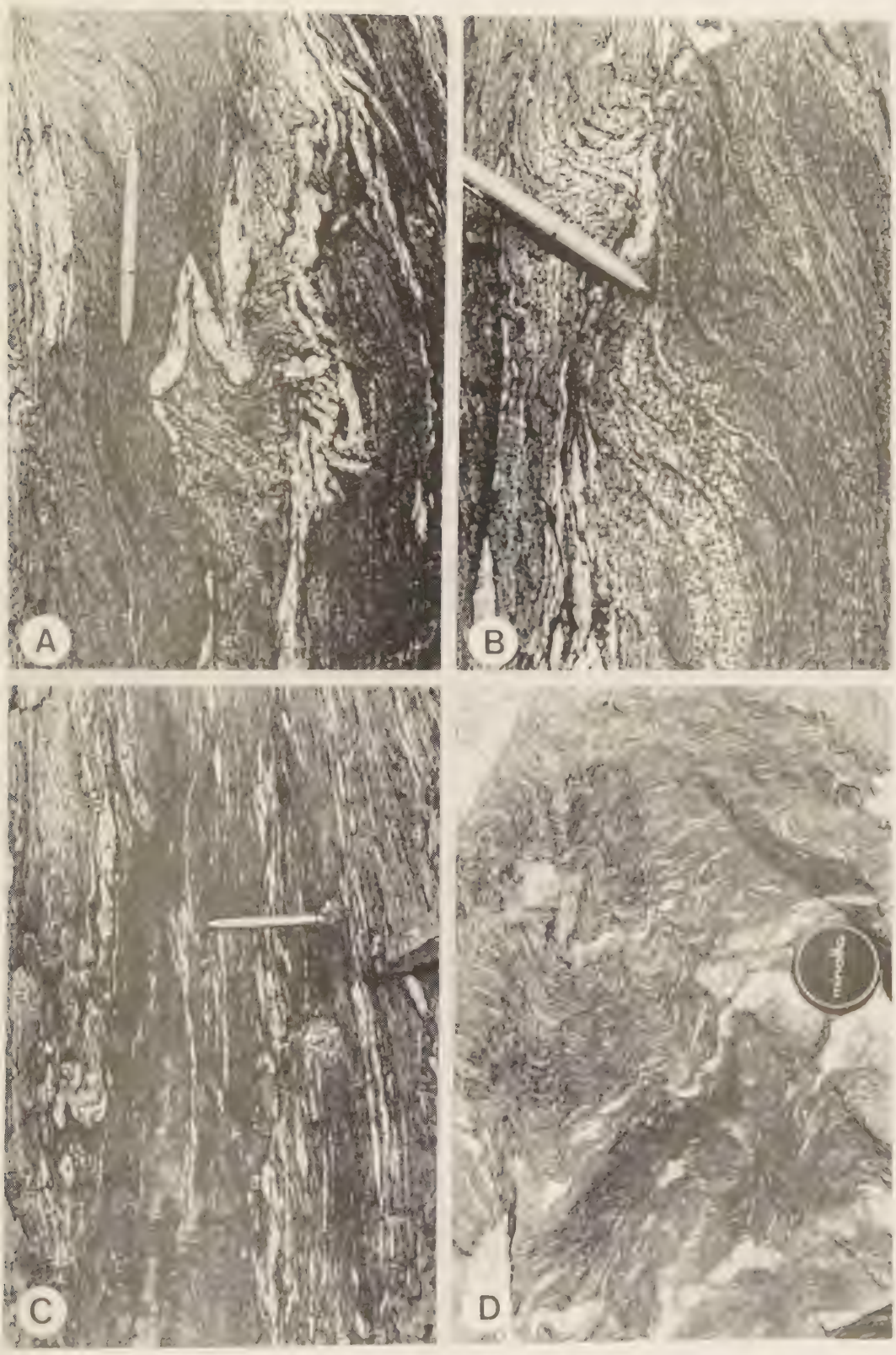


FIG. 6.



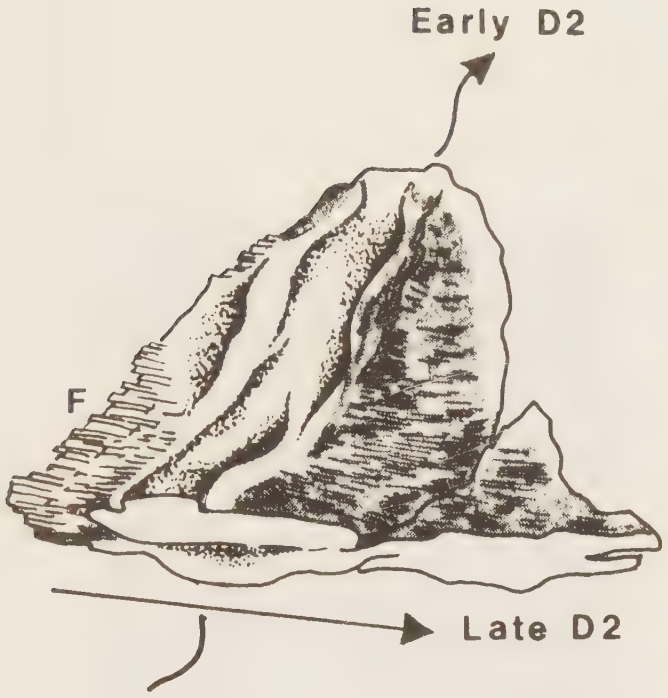
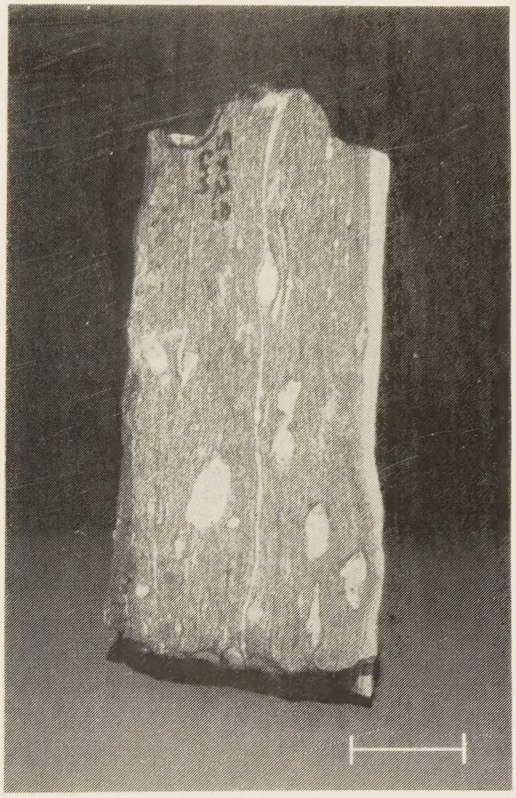

Early D2
F
Late D2

FIG. 8.



Tryckt på Publica-tryckeriet, Lund 1982